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(54) Title: SYSTEM FOR REAL TIME FINGER SURFACE PATTERN MEASUREMENT
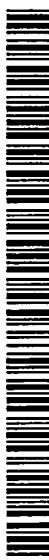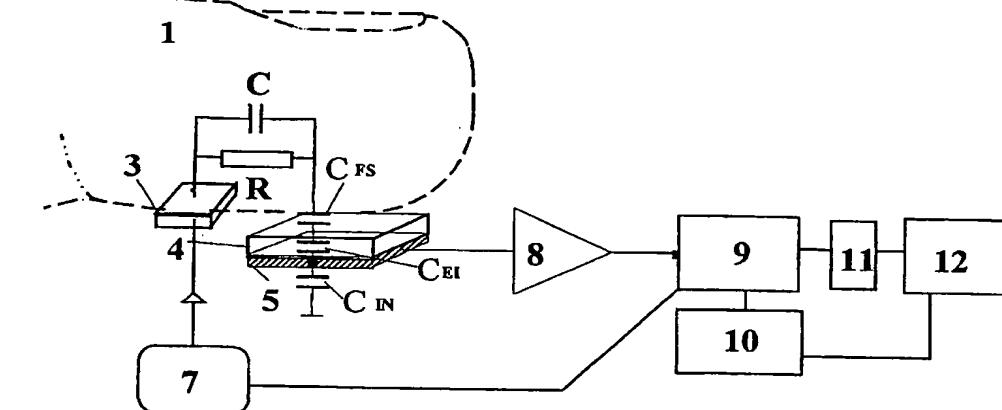
(57) **Abstract:** This invention relates to a system for measuring patterns in a surface, especially in finger surfaces, the system comprising a number of sensor electrodes being provided with an electrically insulating material over which the surface is to be moved, and at least one stimulation electrode for providing a varying current or voltage between the stimulation electrode and the number of sensors through the surface, in which the sensor electrodes constitutes an essentially linear array, that the stimulation electrode is positioned separately from the array of sensor electrodes, that the system comprises a generator coupled to the stimulation electrode for applying a current or voltage with a varying amplitude or phase to the surface, and that the system comprises a measuring unit coupled to the sensor electrodes for, during the application of the current or voltage, measuring the impedance at the sensor electrodes in a time sequence and calculating values of predetermined characteristics of the surface and combining the calculated values for the sensor electrodes over the time sequence for generating a representation of the surface pattern.

SYSTEM FOR REAL TIME FINGER SURFACE PATTERN MEASUREMENT

This invention relates to a system for measuring patterns in a surface, especially in finger surfaces, the system comprising a number of sensor electrodes being
5   provided with an electrically insulating material over which the surface is to be moved, and at least one stimulation electrode for providing a varying current or voltage between the stimulation electrode and the number of sensors through the surface.
10   Biometrics technologies include face recognition using optical or thermal imaging; finger imaging using optical, thermal, AC- and DC-capacitive sensing; hand-geometry measurement and palm scanning; iris and retina scanning; signature recognition; and voiceprints.
15   Finger surface pattern detection and matching is a technique use for identification and verification of persons and of all the biometrics technologies, is the one that currently has received most attention due to its technical capabilities and low cost solutions.
20   U.S. Pat. No. 5,963,679 to Setlak, disclose a fingerprint sensor that includes an array of electric field sensing electrodes that measures the capacitance of the fingerprint by using an AC electric field. The AC electric field method involves using an array of excitation antennas
25   at the base that propagate electric fields through a sensing array to detect fingerprint contours. These fields penetrate the skin surface, originating from the conductive live layer of skin cells beneath the skin surface. This is in contrast to the spherical or tubular field geometries generated by
30   simple capacitive sensors, which only fringe the very top surface of the skin. The method requires that the electrical field is radiated from the sensor to the finger which needs extra shielding for the electronics. In addition, the system uses only a single frequency and do not change and adapt the
35   electrical characteristics (frequency, amplitude, phase) of the electrical field with the characteristics of the finger (dry, wet, etc.) At the same time the area required for realising the sensor is very big which increase the cost and

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limit the area in which the sensor can be used.

Thomson-CSF (now Atmel) uses a linear or an array of
semiconductor temperature sensors to capture fingerprint
images. The finger's ridges are close to the chip and thus
5   conduct heat away more effectively than do the valleys,
which are insulated by a layer of air. The FingerChip as it
is called has a linear shape, allowing the capture of a
fingerprint image by sweeping the finger across the sensing
area. After capturing several images, the software can
10   reconstruct a full fingerprint image. The implementation is
area efficient but the temperature variation of the
environment can make the measurement imprecise.

The present invention relates to a system for real time
finger surface pattern measurement wherein the system is
15   provided with a plurality of electrodes to be placed on the
upper metal layer of multi metal layer silicon or packaging
system, a pair of input electrodes for stimulating the
finger with an electrical variable frequency signal to the
part of the finger and a measuring plurality of electrodes
20   for measuring the voltage at the electrodes of the measuring
electrodes, comprising a current or a voltage generator
providing the measuring electrical variable frequency
signal, a converter for the transformation of the measuring
signal into an electric signal, being a measure of the
25   impedance of the part of the finger surface, and means for
the generation of signals which form a measure for further
variables with the aid of which said parameter can be
determined using a calculating model, said signals encompas-
sing a signal forming a measure for the impedance signal.

30   It is the object of the invention to apply the
measuring results becoming available when employing this
system in such a way that the finger surface pattern can be
determined more accurately.

To this end the system of the invention is
35   characterised in that the current or voltage generator is
separated from the sensing electrodes and measuring
electronics, and is suitable for generating a measuring
electrical variable frequency signal having an amplitude
that can be varied for the different frequencies generated,

in a frequency range of up to about 1000 kHz. This provides
independent measurements for fingers that have different
characteristics (dry, wet etc.). The parameters that can be
determined by means of the system according to the invention
5   include preferably the measuring of the finger surface
pattern, the characteristics of the finger (dry, wet), the
moment when the finger is approaching and comes in contact
with the sensor and the fact that the finger is alive (life
finger detection, dead finger detection).

10   The front end sensors for measuring the finger surface
pattern is formed by a plurality of electrodes, e.g. formed
by a metal or polysilicon layer. The sensors are placed on a
row orthogonal on the movement direction of the finger
(horizontal or vertical) and with a number of sensor
15   elements placed in the movement direction of the finger for
speed measurements. The finger is not in direct contact with
the metal or polysilicon electrodes but via an electrically
isolating material which cover the electrodes. The material
has electrical functions in the measurement principle, is
20   impermeable, has mechanical strengths and protects the
sensor against mechanical stress, electrical discharge,
chemical agents and other external factors. An electrical
signal stimulates the finger and the system determines and
measures in real time the finger surface pattern.

25   It has been determined that the application of
different frequencies for the determination of finger
surface pattern can be used for fingers with different
electrical properties. Signals of different frequencies are
used for the measurement and determination of finger surface
30   pattern. The maximum frequency may, however, be limited to
500 kHz due to radiation problems.

         In addition it is desirable that means are provided for
the determination of maximum phase shift between the
measuring current and the measuring voltage as a function of
35   the frequency. This allows the electric transfer function of
the particular part of the finger surface to be determined,
with the angular frequency being the independent variable.
This permits at the same time the determination of the ratio
between intra and extra cellular fluids and if the finger is

alive or not. This ratio is directly related to the
frequency at which the phase angle is at a maximum. With
persons that have a normal finger this maximum phase angle
is at about 10° at 100 kHz. In addition a temperature sensor
5   may be placed on the system which will determine the
temperature of the finger and correlate with information
related to the electrical characteristics of the finger will
determine if the finger is alive, dead or fake.

The system is preferably provided with connecting means
10   for connecting the current or voltage generator of the
stimulation signal to the finger and realising a good
electrical contact with an electrode that is characterised
by good electrical characteristics and is resistant to
corrosion and wearout. This is one factor that will assure
15   that reproducible measurements are obtained. The stimulation
electrode for injecting the variable frequency into the
finger is placed at close distance around the sensors, and
has special geometry (finger, etc.) and different functions.

Another embodiment of the system according to the
20   invention is characterised in that said system comprises a
current or voltage generator suitable for the generation of
signals at different frequencies, amplitudes and phases.
These frequencies can range from about 10 to 500 kHz.

Another embodiment of the system according to the
25   invention is characterised in that said the system comprises
of a structure with intrinsic ESD (elctro static discharge)
protection.

The ESD protection can be kept to the limits of 2kV if
a number of issues are considered:
30   The ESD protection realised by using a finger discharge
method (finger ground connection via one terminal of the
activation cell) that is used in connection with the power
control mechanism and the activation cell in such a way that
the active electronic blocks of the fingerprint sensor
35   remain grounded until the charge on the finger is removed
and then activated.

The method used to measure the capacitance of the
finger considers that the voltage at the sensor pad is
reduced via the voltage divider realised with the capacitors

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C_{EI} and C_{IN} by a factor in the order of 1000. Typical values
for the capacitance for the capacitors are for C_{EI} in the
range of tens of fF, and for C_{IN} a fez pF. The maximum
voltage limits for the dielectric C_{EI} is determined by the
5   area, thickness and permeability of the electrically
isolating material. The structure has intrinsic increased
ESD at two levels. From finger to ground via the isolating
layer and from the sensor pads from the input of
electronics.
10   The output of the variable frequency generator should
be coupled via an ESD protection circuit that assume 20KV
ESD before it is applied to the stimulation electrode and
finger.
           Another embodiment of the system according to the
15   invention is characterised in that said system comprises an
activation cell suitable for detection when the finger is
approaching and contacts the sensor. Contact cell or
activation cell detects when the finger gets in contact with
the surface of the cell and a change in electrical charact-
20   eristics, preferably impedance" is determined between the
electrodes and this change is converted into an electrical
signal which starts and power up the whole system. The
activation cell may be a dedicated sensor in the sensor
array, or a separate sensor. A separate sensor may be of
25   any available type, e.g. sensing changes in the capacitance
close to the sensor, temperature or optical detectors.
           Another embodiment of the system according to the
invention is characterised in that said the system comprises
a structure that is suitable for navigation/mouse uses, e.g.
30   in relation to a display, by moving the finger along the
sensors plane.
           Another embodiment of the system according to the
invention is characterised in that said the system comprises
of electrode with multiple functions (activation cell,
35   electrical characteristic measurement for the finger,
stimulation electrode). The electrode has different
functions depending on the operating mode of the system:
           In measurement or detection mode has a function of
stimulation electrode connected to the output of a variable

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frequency generator, which introduces into the finger the
electrical stimulation variable signal. The connection to
the finger can be AC or DC.

     In wait mode has a function of contact sensor, which
5 detects when a finger is approaching the system and when is
contacting the sensor. In this mode the structure of the
electrode is split into two electrodes with a distance
between. Can be used for ESD protection if one of the
electrodes of the structure is coupled to ground.

10   The sensor may also be adapted to detect whether the
finger is dead or alive by measuring the electrical
characteristics, preferably impedance, of the finger and to
detects and measure the electrical characteristics,
preferably impedance, of the finger and determine if the
15 finger is dry or wet in order to generate the appropriate
frequency with the right amplitude and phase to have a
maximum signal.

     The invention provides a number og advantages over the
known technology, obtianing a very small area that may not
20 likely be obtained by any methods available today. The
system is five times smaller than the apparatus described in
U.S. Pat. No. 5,963,679. In addition it and the related
circuitry is compact and may be built with commercial
technology, e.g. in a silicon process with multiple metal
25 layers.

     The invention will now be further described with
reference to the figures illustrating the invention by way
of example.

Fig. 1   represents schematically a first measuring
30   arrangement of the system according to the
             invention;

Fig. 2   represents schematically a second measuring
             arrangement of the system according to the
             invention and which explains the inherited
35   navigation/mouse (x, y) characteristics of the
             system;

Fig. 3   represents schematically the electro static
             discharge (ESD) protection via the electrically
             isolated capacitor CEI;

Fig. 4   shows one difference between the invention and the
            known art.

Fig. 5   shows a typical progress of an impedance signal.

            Fig. 1 shows a block diagram of an embodiment of the

5   system for carrying out simultaneous measurements on a
    finger. By means of a stimulation electrode 3 a current or
    voltage from a generator 7 is supplied to the finger 1. The
    voltage or current generator is adapted to provide a vari-
    able amplitude, frequency and/or phase signal to the elect-

10 rode 3. The signal resulting from current passing through
    the tissue of the finger, the finger surface, and the
    electrically insulating material 4 that separates the finger
    surface from the sensor electrode 5 is measured by means of
    the electrode 5, which is connected with a front end analog

15 reading circuit 8 including a low noise amplifier.

            The output of the front end analog reading circuit 8 is
    supplied to a calculating element 9 which provides an
    electric impedance signal which is directly related to the
    impedance of a locally measured part of the finger 1 as a

20 function of the time and a phase signal which is directly
    related to the phase difference between the current or
    voltage supplied into said part of the finger 1 and the
    resulting voltage over that part of the finger as measured
    by means of the electrode 5.

25   The electric signal is fed into the digital signal
    processing unit 12 through an interface 11 comprising an
    analog to digital converter in order to determine a
    parameter to determine the electrical characteristics of the
    finger (dry, wet) and if the finger is dead or alive. The

30 processor 12 preferably controls the frequency, phase and
    amplitude of the current or voltage generator and adaptively
    adjust these parameters based on the finger's electrical
    characteristics.

            Also, the digital processing unit 12 receives

35 information from all the sensors related to the fingerprint
    scanner, calculating a representation of the finger surface
    being usable for identification purposes.

            Figure 4 shows one difference between the invention and
    the known art described in U.S. Pat. No. 5,963,679. The main

difference between the two concepts lies in how the intrin-
sic, parasitic capasitance C_{IN} to the amplifier is coupled.

In the U.S. Pat. No. 5,963,679, the capacitance C_{IN} is
coupled in parallell with the capacitance of the ridges or
5   valleys to be measured while an excitation electrode
generates an electric field via a fixed capacitor. This
concept puts a very heavy demand on the input impedance
characteristics of the amplifier, which must not be too
large in comparison with the value of the capacitance of the
10   ridges or valleys, which is usually much lower than 100 fF.

This problem is avoided by using the concept according
to this invention, represented in Fig. 1. Here the stimula-
tion signal is applied directly to the finger and the capa-
citance C_{FS} of the ridges or valleys is connected in series
15   with the capacitance of the electrically isolating material
C_{EI}. The value of C_{IN} may be in the order of few pF, without
degrading the measurement principle. Thus concept described
in this application is much less sensitive to the amplifier
performance and can measure signals with aplitudes of 1 mV
20   or less. The known art described in U.S. Pat. No. 5,963,679
requires a desirably 5 to 10 mV from the sensing elements.

Fig. 5 shows a typical progress of an impedance signal
with amplitude A, as measured with the low noise phase
sensitive amplifier based on a stimulation by current or
25   voltage source. The progress of this signal is time T
dependent because of the movement activity of the finger.
The data is stored and process in real time by a local or
remote processor.

In accordance with the invention, referring again to
30   fig. 1, measuring errors due to offset, dc levels, gain,
wearout of the electrically isolating material on the top of
the sensors and of the stimulation electrode of the system
or due to measurements carried out under conditions where
the normal moisture balance of the finger surface is upset
35   (dry, wet fingers), are prevented due to the fact that the
current or voltage stimulation generator 7 can generate an
electric signal having variable amplitudes and frequencies.
In accordance with the invention a set of calibration data
is provided for these parameters. The calibration data is

stored into a calibration memory block 10 in the illustrated embodiment being coupled to the analog processor 9 as well as the digital prosessing unit 12.

By processing the data from current or voltage
5   generator 7 in an analog element 9 the measuring results becoming available from the front end analog reading circuit 8 are converted into a signal being proportional to the impedance. The current voltage generator 7 is adapted to generate currents or voltages having different frequencies
10 with different amplitudes and phases. *The analog processor 9 is connected to the generator 7 and comprises means for detecting the phase differences between the generated and the measured signals.*

In a particular embodiment the current voltage
15 *generator 7 is suitable for the generation of an electric stimulation signal having a frequency sweep of about 10 kHz to 500 kHz, while the calculation element 9 is also suitable for the determination of the maximum phase angle dependent on the frequency. The generator 7 may also be connected to*
20 *the processing unit 12 for controlling the generated signal relative to the measured values.*

Similarly, a local impedance measurement can be carried out by means of the electrode pairs. The measurement results becoming available through the measuring front end analog
25 reading circuit 8, together with data from the current voltage generator are fed into a processor 9, and from these a local impedance value and the phase angle between the current from the generator and the voltage from the amplifier are determined.
30   The processor 9 generates signals for the control of the   front end analog circuit 8. The processor unit 12 preferably generates the amplitude, phase and frequency control signals.

Figures 2a and 2b illustrates fingerprint scanner.
35 according to the invention. The fingerprint scanner here comprising a number of elektrodes constituting a linear array of electrodes 20 being placed orthogonal to the direction of the movement of the finger to scan the fingerprint by each measuring the capacitance of parts of

the fingerprint, and as well a number of sensors parallel
with the direction of movement 21 and serving for speed
measurements.

The electric system is prone to the development of
5   electromagnetic stray fields. The provision of the
stimulation electrode 3 that is in direct contact with the
finger, reduces these stray fields since the finger is
absorbing the energy of the signal, and at the same time
there is a grounded layer on the sensor. Each sensor
10   electrodes 20 being surrounded by a grounded shield 24.

The role of the grounded ring 24 is:
-    An electrical lens that concentrates the electrical
     signal from the finger to the sensor electrode.
-    Provide a protective electrical layer for the sensor
15   against the signal radiation generated by the frequency
     stimulation electrode.
-    Provides a protection and separation between adjacent
     sensor electrodes.
-    The grounded ring can be made with two metals layers.
20   Metal layer that separate the sensors and a metal layer
     on the top.

Figure 3 illustrates an embodiment of the invention
being provided with electrostatic discharge (ESD) protection
means 31, 32 for protection via the insulated capacitor C_{EI},
25   being positioned between the surface and the sensor pad 5.
In addition ESD protection means 30, 32 are positioned
between the generator 7 and the stimultation electrode, as
well as between the sensor pad 5, the circuitry, ground and
a power supply 34.

30   To summarize the invention relates to a system for real
time finger surface pattern measurement, wherein the system
is provided with a plurality of electrodes 5 and a electri-
cally isolating layer 4 on the top of the electrodes 5 on
which the finger 1 is applied and moved, an input electrode
35   3 for stimulating the finger with a variable current or
voltage to the part of the finger and a measuring plurality
of electrodes, 5,20 for measuring the signal at the sensor
electrodes, comprising a current or voltage generator 7
providing the stimulating signal, a converter for the

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transformation of the measuring signal into an signal being
a measure of the impedance of the part of the finger.

The current or voltage generator 7 has a minimal
radiation configuration and is suitable for generating a
5   measuring current or voltage having a variable amplitude and
phase on different frequencies.

The measured parameter is a characteristic of the
finger surface pattern configuration, e.g. the impedance of
different points from the finger surface.

10   The current or voltage generator 7 is adaptive
responding to control signals from the system adapting the
generated current or voltage to measured characteristics of
the surface, having variable amplitude, frequency and phase.

The system is preferably provided with a plurality of
15   electrodes 20 for measuring the impedance of the parts of
the finger, and transversal electrodes 21 for measuring the
speed of the finger movement over the sensor's electrodes
and thus having inherited navigation/mouse characteristics.

The system is provided with detection means 23, e.g.
20   related to the stimulation electrode of the current or
voltage generator, in order to determine when the finger is
approaching and contact the sensor activation cell.   These
means may also carry out the local impedance measurement of
the finger and to determine its biological characteristics
25   (dry, wet etc.) in order to change the frequency, amplitude
and phase of the stimulation signal, or local impedance
measurement and temperature of the finger and to determine
if the finger is dead, alive or fake.

The system may also be provided with means for the
30   determination of maximum phase shift between the measuring
current or voltage and the measuring voltage as a function
of the frequency.

Usually the system according to the invention will be
provided with one stimulation electrode.   In some cases,
35   however, a number of stimulation electrodes may be used.

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Claims

1.   A system for measuring patterns in a surface, especially in finger surfaces, the system comprising a number of sensor electrodes being provided with an electrically insulating material over which the surface is to be moved, and at least one stimulation electrode for providing a varying current or voltage between the stimulation electrode and the number of sensors through the surface,
c h a r a c t e r i z e d in that the sensor electrodes constitutes an essentially linear array,
      that the stimulation electrode is positioned separately from the array of sensor electrodes,
      that the system comprises a generator coupled to the stimulation electrode for applying a current or voltage with a varying amplitude or phase to the surface, and
      that the system comprises a measuring unit coupled to the sensor electrodes for, during the application of the current or voltage, measuring the impedance at the sensor electrodes in a time sequence and calculating values of predetermined characteristics of the surface and combining the calculated values for the sensor electrodes over the time sequence for generating a representation of the surface pattern.

2.   System according to claim 1, wherein it also comprises at least one electrode coupled to the measuring device and being positioned outside the linear array for measuring of the surface movements relative to the sensor array.

3.   System according to claim 1, wherein the variation in current or voltage is in the range of 10-500kHz.

4.   System according to claim 1, wherein the variatin in current or voltage comprises frequency sweeps over a chosen frequency range, e.g. 10-500kHz.

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5.   System according to claim 1, wherein the sensor
electrodes are coupled to a measuring instrument for
detection of amplitude of the signal and phase differences
between the signal from each sensor electrode and the
applied varying current or voltage, and from this create a
representation of the variation of the impedance along the
sensor array.

6.   System according to 1, wherein each sensor electrode is
surrounded by an electrically grounded ring of a conducting
material.

7.   System according. to claim 1, wherein the stimulation
electrode adapted to be electrically coupled to the surface.

8.   System according to claim 1, wherein the varying
voltage or current is applied to the stimulation electrode
in a predetermined time sequence.

9.   System according to claim 1, also comprising an
actiation sensor for activating the system upon the approach
of a surface.

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Fig. 1
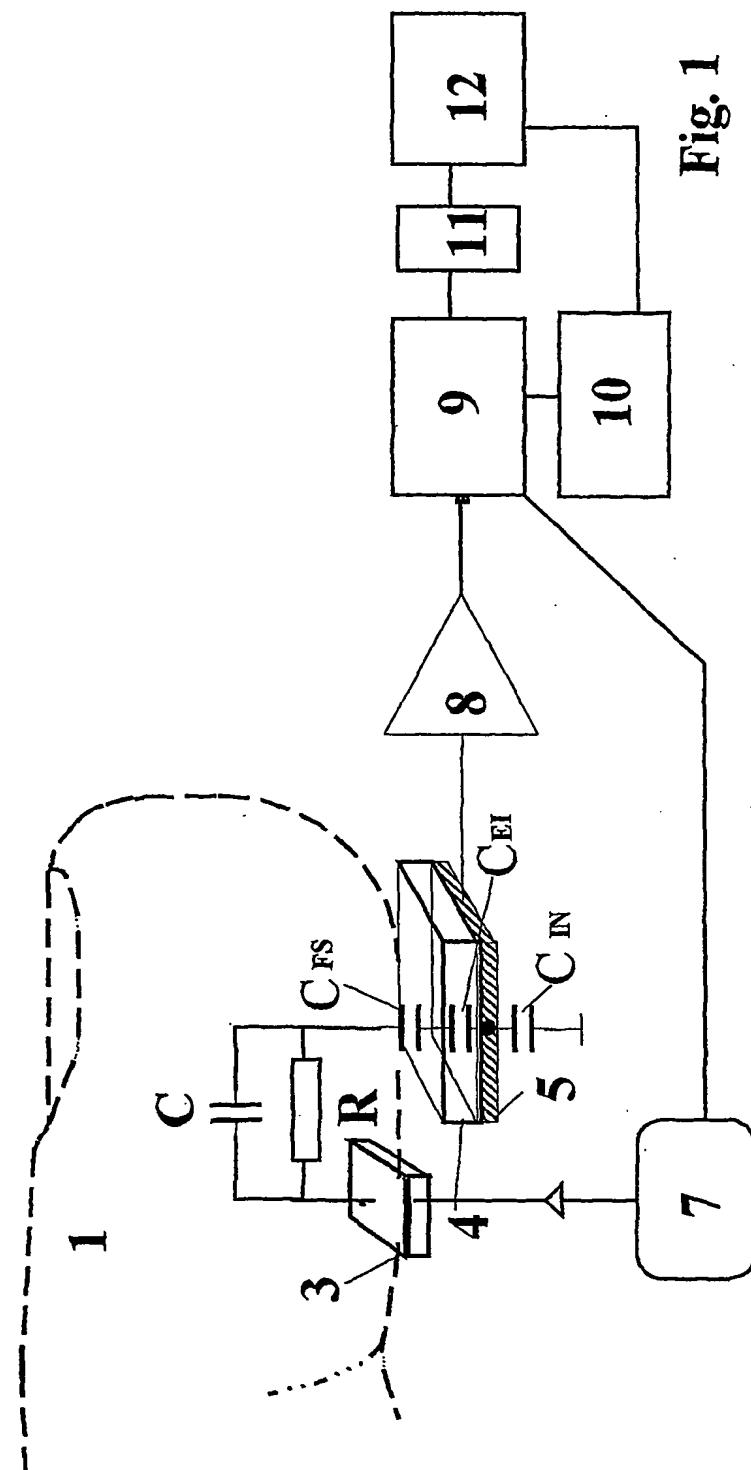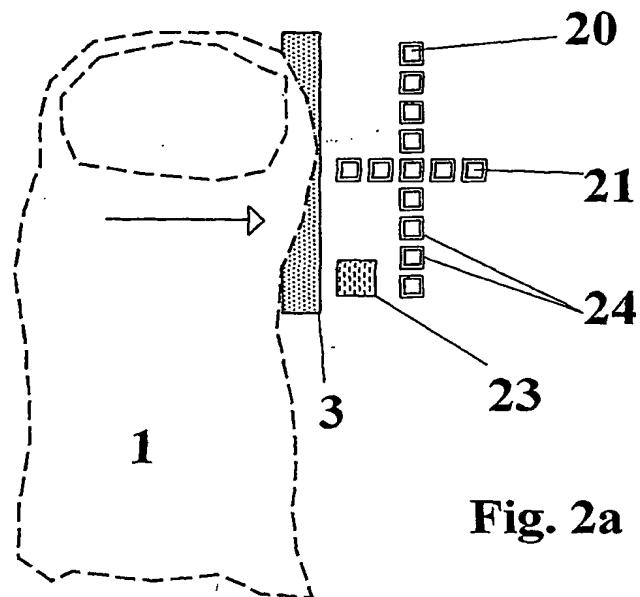
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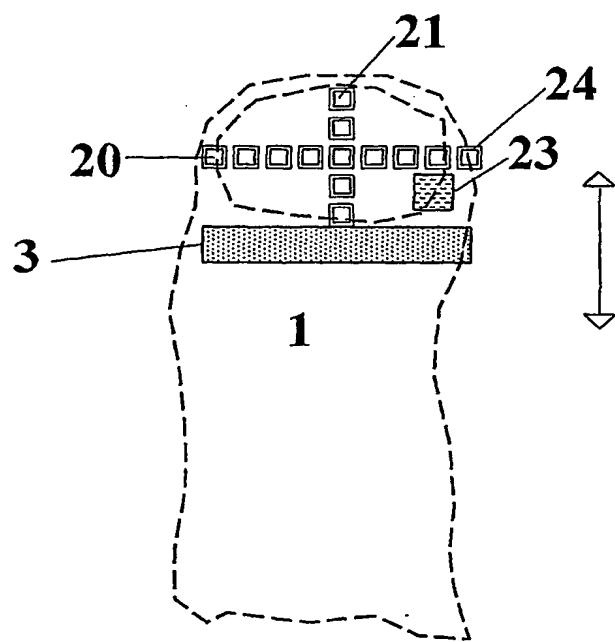
Fig. 2b
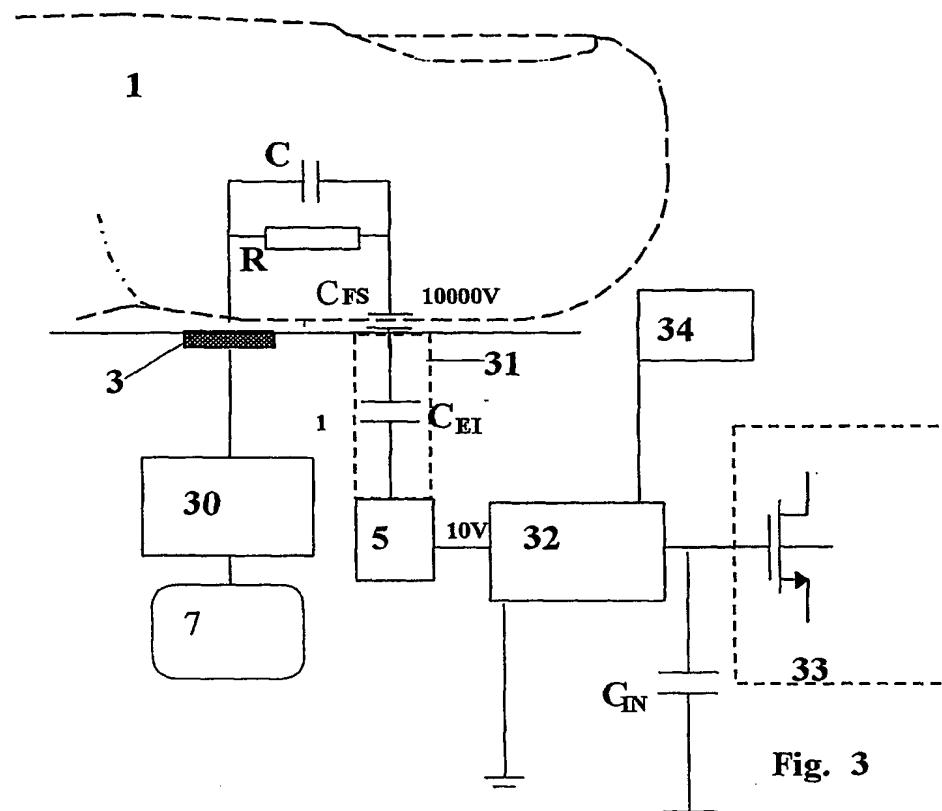
Fig. 3

Excitation Drive
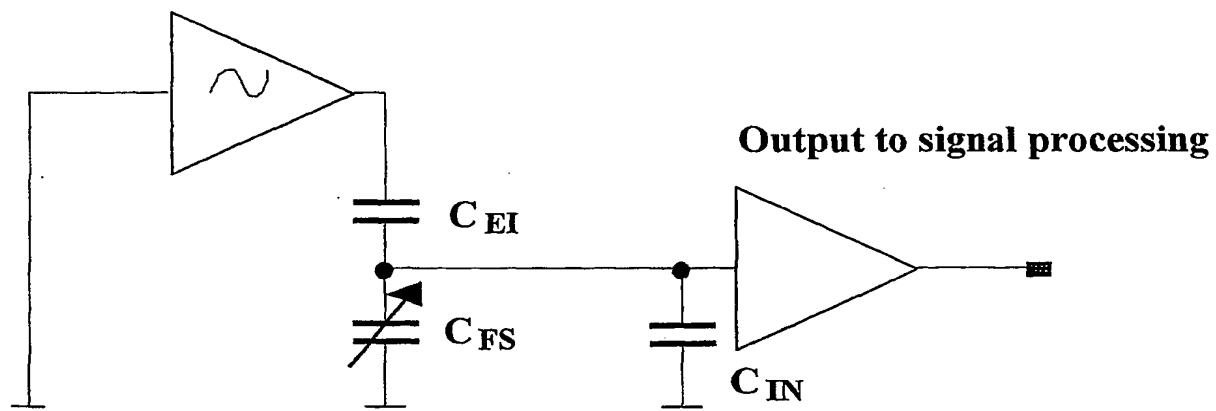
Output to signal processing

Fig. 4

FIG. 5